MODELING AND IMPLEMENTATION OF SPACE VECTOR MODULATION FOR THREE-PHASE DIRECT TORQUE CONTROL MATRIX CONVERTER

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

m	Modulation index
V_{pn}	DC-link voltage
T_s	Sampling period
η	Efficiency
f_1, f_2	Stator and rotor frequency
Γ_r	Rotor time constant
ψ_{rd}, ψ_{rq}	*dq* rotor flux.
$\psi_{sd,}$ ψ_{sq},	*dq* stator flux
$\vec{\lambda}_r$	Rotor flux linkage space vector
$\vec{\lambda}_s$	Stator flux linkage space vector
$\vec{\mathrm{i}}_{\mathrm{p}}$	VSI averaged input current
$\sin(\emptyset_i)_Q$	output power factor regulator
$\sin(\emptyset_i)_f$	observed value of power factor regulator
$\sin(\emptyset_i)_g$	given value of power factor regulator
$\vec{\mathrm{T}}_{\mathrm{ph}}$	Transfer matrix
$\vec{\mathrm{T}}_{\mathrm{VSI}}$	Space vector representation of transfer matrix of VSI
$\vec{\mathrm{T}}_{\mathrm{VSR}}$	Space vector representation of transfer matrix of VSR
$\vec{\mathrm{V}}_s$, $\vec{\mathrm{V}}_r$	Stator and rotor voltage space vector
$\vec{I}_{i_{ref}}$	Reference current vector
$\vec{I}_a, \vec{I}_b, \vec{I}_c$	Space vector representation of input current *a*, *b* and *c*
$\vec{I}_i, \vec{I}_o$	Space vector representation of input and output current
$\vec{V}_{o_{ref}}$	Reference voltage vector $\vec{V}_o$
$\vec{V}_i, \vec{V}_o$	Space vector representation of input and output voltage

$\vec{V}_{pn}$	Space vector representation of DC-link voltage
$\emptyset_L$	Phase angle between the load current and the load voltage
$\emptyset_i$	Phase angle between the input current and the input voltage
$\emptyset_o$	Phase angle between the output current and the output voltage
$\cos\varphi$	Power factor
$C_{3/2}$	$3/2$ transformation matrix of the *abc* frame to *dq* frame
I_j	The switch stage of the inversion stage
I_{om}	Maximum output current
L_{lr}	Rotor leakage inductance
L_s, L_r, L_m	Stator, rotor and the magnetizing inductance
R_i	The switch stage of the rectification stage
R_s	Stator resistance
T_L	load torque
T_e	Electromagnetic torque
V_0	Zero voltage vector
V_a, V_b, V_c	Input voltage *a*, *b* and *c*
V_{ab},V_{ac}	Inputs line-to-line voltages
V_{im}	Maximum input voltage
V_{iph}	Input phase voltage
V_{sd}, V_{sq}	Stator voltage at *d* and *q* frame
V_u, V_v, V_w	Output voltage *u*, *v* and *w*
$V_u(t)$, $V_v(t)$, $V_w(t)$	Instantaneous output voltage *u*, *v* and *w*
V_x	Flux controller loop to SVM
V_y	Output torque controller loop to SVM
d_{α_vi},$d_{\beta\alpha\_vi}$	Switching vector duty cycles

$e_{\psi s}$	Error for stator flux
i_{sd}	Stator current at *d* frame
$k_{p\psi'}$	Proportional gain for flux
m_i	VSR modulation index
m_v	Input voltage modulation index
p_n	Number of poles
$\varepsilon_{\emptyset_i}$	Tolerance
θ_v, θ_i	Input and output arbitrary angle
ω_0	Output angular velocity
ω_i	Input angular velocity
$\Delta\omega^B$	Rotor angular frequency corresponding to the maximum point of the slip frequency
$\Delta\omega$	Slip frequency
c_1 , c_2	Acceleration coefficients
gbest	Best particle among the entire population
I	Inversion stage
i_{ar}, i_{br}, i_{cr}	Rotor current
i_{as}, i_{bs}, i_{cs}	Stator current
I_{dc}	DC current generator
J	Moment of inertia
M	Modulation matrix
P	Active power
$pbest_i$	Best previous position of x_i
Q	Reactive power
R	Rectification stage

$rand_1$, $rand_2$	Random functions
T	Converter transfer matrix
v_i	rate of the velocity for particle x_i
w	Inertia weight factor
x_i	*ith* particle
J	Moment of inertia
ω	Angular velocity

LIST OF ABBREVIATION

ANN	Artificial Neural Network
ASVM	Asymmetrical SVM
DMC	Direct Matrix Converter
DSP	Digital Signal Processing
DTC	Direct Torque Control
IDP	Isolated Driver Potentials
IGBT	Insulated Gate Bipolar Transistor
IM	Induction Motor
IMC	Indirect Matrix Converter
IPID	Intelligent PID
ITF	Indirect Transfer Function
MC	Matrix Converter
PWM	Pulse Width Modulation
SMC	Sparse Matrix Converter
SSVM	Symmetrical SVM
SVM	Space Vector Modulation
THD	Total Harmonic Distortion
USMC	Ultra Sparse Matrix Converter
VSI	Voltage Source Inverter
VSMC	Very Sparse Matrix Converter
VSR	Voltage Source Rectifier
VVVF	Variable Voltage Variable Frequency

ABSTRACT

Matrix converter (MC) as induction motor drivers have received considerable attention because of its high integration capability and the higher reliability direct AC-AC power converter without any bulky DC link component. It can provide sinusoidal output current and input current, adjustable input power factor, and regeneration capability; and very attractive in areas where volume, efficiency and reliability are important. Widespread, systematic, and in-depth studies have been focused on the modulation algorithm and the commutation strategy of the MC, and the key technologies for its application in induction motor drive system. In this thesis, the main aim is to improve the performance of the induction motor drive based on the space vector modulation (SVM) method. In addition, some improvement is performed which are by using close-loop induction motor drive controller based on the relations of the efficiency and power factor with the rotor frequency and slip frequency in a steady state mathematical model and second, enhancing this controller by replacing the PI controller with the combination of Direct Torque Control (DTC) and Particle Swarm Optimization (PSO). The combination of DTC-PSO technique generates the required voltage vectors under 0.86 input power factor operations and it also gains the change regularity between efficiency and power factor. The duty cycles of the switches are modeled using SVM for 0.65 voltage transfer ratios. The mathematical models for the proposed systems are implemented by using *Matlab/Simulink* for different speed and load. Finally, the whole system has been verified from the experiments and the output voltage, and the input current generated by the model of the converter. The results demonstrate the good quality and robustness in the system dynamic response and a reduction in the steady-state and transient motor ripple torque.

ABSTRAK

Kebelakangan ini, matrik penukar (MC) sebagai pemandu motor induksi telah menerima perhatian kerana keupayaan integrasi yang tinggi dan kebolehpercayaan yang lebih tinggi sebagai penukar kuasa langsung AC-AC tanpa meggunakan sebarang komponen sambungan DC yang sangat besar. Ia boleh menyediakan arus keluaran dan arus masukan yang sinusoidal, faktor kuasa masukan boleh laras, dan keupayaan penjanaan semula; dan ia sangat menarik digunakan pada keadaan kecekapan isipadu dan kebolehpercayaan adalah penting. Fokus kajian yang meluas, sistematik, dan mendalam telah dilakukan kepada modulasi algoritma dan strategi peringanan MC, dan juga teknologi utama bagi kegunaan dalam sistem pemacu motor aruhan. Tujuan utama tesis ini adalah untuk meningkatkan prestasi pemacu motor aruhan yang berdasarkan ruang vektor kaedah modulasi (SVM). Di samping itu, beberapa pembaikan dilakukan yang dengan menggunakan pemacu motor aruhan litar-tutup berasaskan hubungan kecekapan dan faktor kuasa dengan frekuensi pemutar dan frekuensi gelinciran di dalam keadaan mantap dan kedua meningkatkan pengawal ini dengan menggantikan pengawal PI dengan gabungan Kawalan Langsung Daya Kilasan (DTC) dan Particle Swarm Optimization (PSO). Gabungan teknik DTC-PSO menjana vektor voltan yang diperlukan di bawah 0.86 operasi input faktor kuasa dan ia juga mendapat kekerapan menukar antara kecekapan dan faktor kuasa. Kitaran bekerja suis dimodelkan menggunakan SVM bagi nisbah pemindahan voltan 0.65 Model matematik untuk kawalan langsung MC berasaskan SVM dilaksanakan dengan menggunakan *Matlab/Simulink* untuk kelajuan dan beban yang berbeza. Akhir sekali, seluruh sistem telah disahkan dari eksperimen dan voltan keluaran, dan arus masukan yang dihasilkan oleh model pengubah. Keputusan menunjukkan kualiti yang baik dan kekukuhan dalam sistem gerak balas dinamik dan pengurangan dalam riak daya kilasan motor keadaan mantap dan fana.

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